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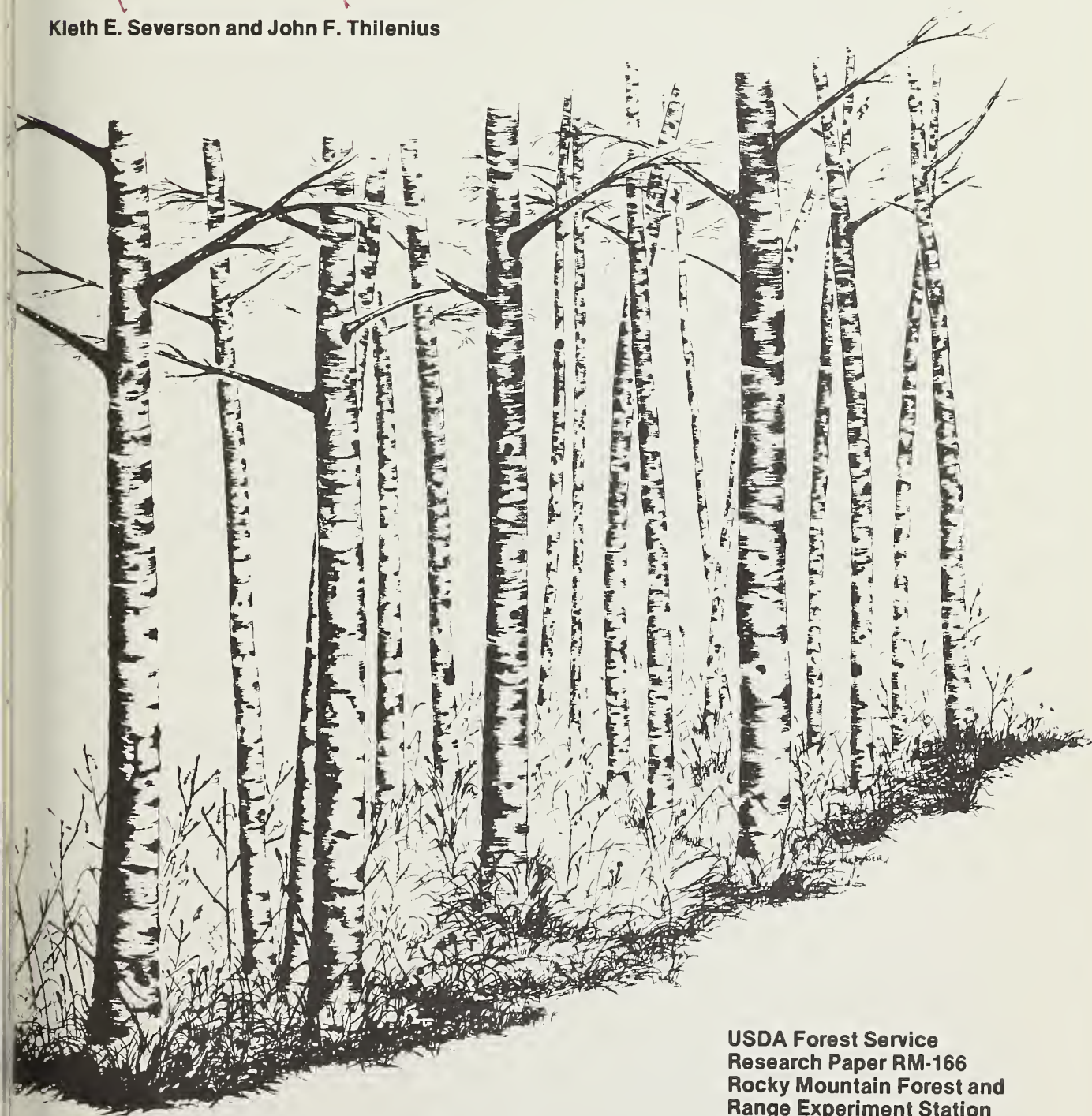
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Classification of Quaking Aspen Stands in the Black Hills and Bear Lodge Mountains

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Abstract

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Aspen forests were classified into nine "Aspen Groups" by cluster analysis of a similarity matrix. Attributes used in analysis were based on vegetation, soils, and site characteristics. Aspen Groups were defined at a minimum similarity level of 60 percent. Relationships of soils, flora, and vegetation dynamics—within and between Aspen Groups—are discussed. Aspen Groups delineated by this method can be functional units for both research and management purposes.

Keywords: Quaking aspen, *Populus tremuloides*, classification, cluster analysis, synecology.

Classification of Quaking Aspen Stands in the Black Hills and Bear Lodge Mountains

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Background

Quaking aspen (*Populus tremuloides*), hereafter referred to as aspen, occupies about 5 percent of the total land surface of the Black Hills and Bear Lodge Mountains. The esthetic importance of aspen has long been recognized, and foresters have recently become interested in aspen forest types for possible use as firebreaks or green belts. Aspen stands are also important as wildlife habitat, particularly for white-tailed deer and ruffed grouse. The aspen understory is one of the most varied and productive types in this region, and is a preferred forage source for domestic livestock.

The objectives of this study, begun in 1970, were to measure differences in productivity, composition, and nutritive value of the understory in different kinds of aspen stands, and from this data, determine which are most valuable for herbivores.

The first problem encountered, however, involved selection of study sites. The kinds of data we were to collect obviously prevented analysis of every stand in the study area. We had to select typical or representative aspen stands that could be intensively studied to yield results that could be applied to most aspen communities in the region. We are reporting here the findings of an initial phase of the study—inventory and classification of aspen stands. Each classification grouping represents a similar set of stands from which a selection can be made for intensive analyses.

Study Area

Location and Geology

The Black Hills and Bear Lodge Mountains, totaling about 3.3 million acres, are included for the most part in the Black Hills National Forest.

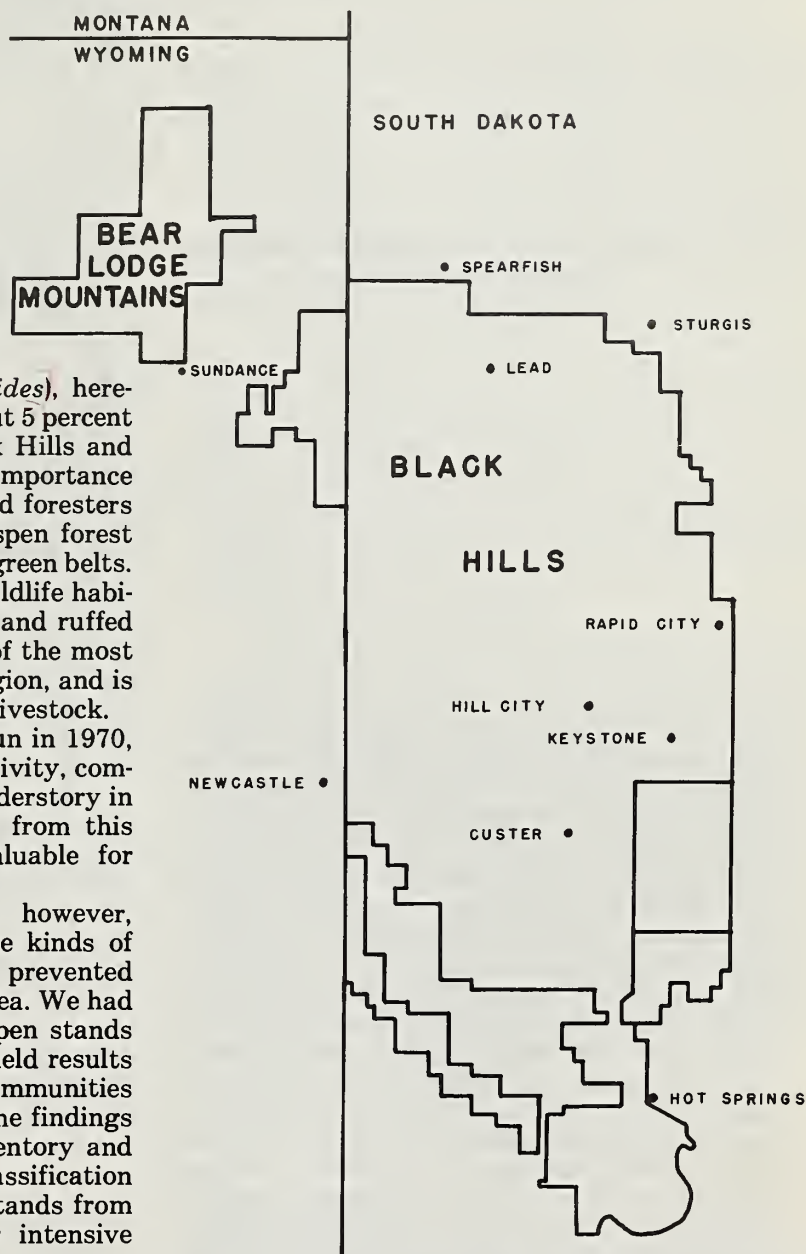
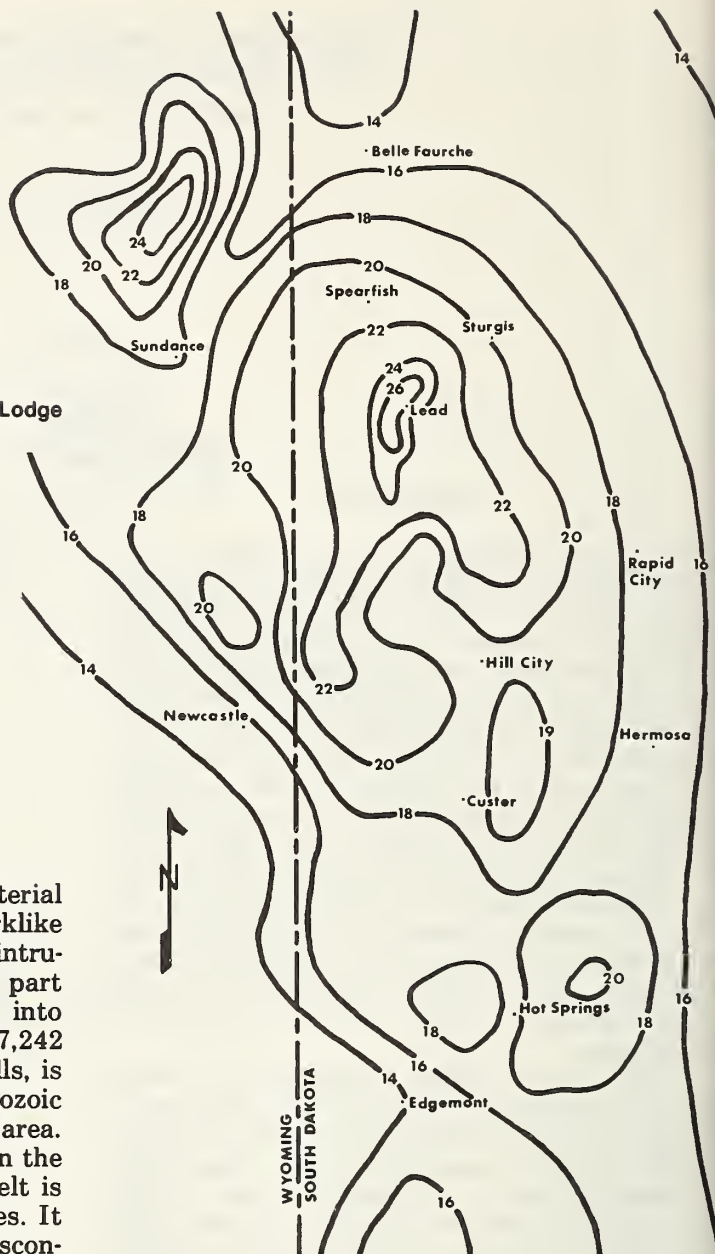


Figure 1.—Location of Black Hills and Bear Lodge Mountains.

About two-thirds of this area is in western South Dakota, and the remaining one-third in north-eastern Wyoming (fig. 1).

The Black Hills are an elongated, dome-shaped mass arising from the Northern Great Plains. The central area is composed of highly

Figure 2.—Isohyetal map of Black Hills and Bear Lodge Mountains (from Orr 1959).



dissected Precambrian metamorphic material with a complex of ridges, peaks, and parklike valleys (McIntosh 1949). There is one major intrusion of Precambrian granite in the southern part of the central area, which has weathered into vertical cliffs and rock spires. Harney Peak (7,242 feet), the highest elevation in the Black Hills, is an isolated summit in this region. A Paleozoic limestone plateau surrounds the central area. This limestone formation is 15 miles wide on the western side. On the east, the limestone belt is very narrow and almost disappears in places. It forms steep cliffs and outcrops along the discontinuity between the limestone and other formations, and along canyons. Along the northern edge of the Black Hills there is a series of Tertiary igneous intrusive rocks, which form a rugged topography characterized by barren talus slopes.

The Bear Lodge Mountains are a smaller, dome-shaped mass northwest of the Black Hills. The highest elevation is Warren Peak at 6,656 feet, an igneous intrusive mass similar to those in the northern Black Hills. This area is immediately surrounded by Paleozoic limestones. The remainder of the Bear Lodge Mountains is composed primarily of Mesozoic rocks, primarily limestone and shale in the south with more sandstone in the north.

Climate

Average annual precipitation ranges from less than 18 inches at the lower elevations to over 26 inches at the higher elevations in the northwestern Black Hills (fig. 2). Most precipitation falls as rain during May and June, although yearly snowfall does reach 93 inches at Sundance, Wyoming, and exceeds 100 inches at the higher elevations southwest of Lead, South Dakota.

Temperatures exhibit the variation typical of a continental climate. Average annual temperatures in the Black Hills vary from 41°F (Sundance) to 48°F (Hot Springs), with an extreme range of -40° to 112°F. Temperature inversions are also common during winter.

Vegetation

The vegetation in the Black Hills and Bear Lodge Mountains is dominated by *Pinus ponderosa*. About 2 million of the 3.3 million acres of the area are covered with this species. *Picea glauca* is the dominant species on north-facing slopes on Harney Peak in the southern Hills, and on the high-elevation limestone plateau in the northwestern Hills. *Juniperus scopulorum* dominates some locales in the southern Hills.

Deciduous forest types are represented by *Populus tremuloides* and *Betula papyrifera*. Both are found in pure as well as mixed stands on mesic sites. *Quercus macrocarpa* reaches tree form at lower elevations in moist situations around the Bear Lodge Mountains, and on the northwest, north, and east sides of the Black Hills. *Ulmus americana*, *Acer negundo*, *Fraxinus pennsylvanica*, *Ostrya virginiana*, and several *Populus* spp. occur along drainages at lower elevations. Streamside associations at higher elevations include *Salix bebbiana*, *Cornus stolonifera*, and *Betula occidentalis*.

Shrub zones, characteristic of western mountain ranges, are not well represented in the Black Hills. A very narrow band of *Cercocarpus montanus* is found on limestone-derived soils in the southern and southwestern Hills. Irregular pockets of a shrub form of *Quercus macrocarpa* are scattered along the western and northern Black Hills and Bear Lodge Mountains.

Grassland types are also scattered throughout the Hills. A mixed prairie type is found on drier, shallow soils. Moist grassland areas with deep soils are dominated by *Poa* spp.

Literature

The flora of the Black Hills has been well described. Keys and descriptions of all plant species found in South Dakota (Van Bruggen, in press) have recently been completed and include the Black Hills. Thilenius (1971) listed 1,759 taxa as occurring in the Black Hills and Bear Lodge Mountains.

Thilenius (1972) classified the *Pinus ponderosa* type into 13 "habitat units" by cluster

analysis of a similarity matrix based on vegetation, soil, and site attributes of 100 randomly located stands. A summary report of silviculture of *Pinus ponderosa* in the Black Hills has also been completed (Boldt and Van Deusen 1974).

The *Populus tremuloides*/*Betula papyrifera* type has received some attention, primarily because of its importance as deer summer range. Schneeweis et al. (1972) sampled the overstory and understory in four *Populus tremuloides* stands. They concluded that the understories were significantly different on all four stands, primarily due to variability in grass cover. This information was gathered as part of a deer food habits study in the aspen type.

Kranz and Linder (1973) compared the importance of *Populus tremuloides* types to mixed *Populus tremuloides*/*Pinus ponderosa* for deer and cattle. Detailed measurements of both the overstory and understory were made on each of the three types in three different locations in the north-central Black Hills. Use by cattle and white-tailed deer was determined by fecal counts. Cattle tended to use the aspen communities, whereas deer preferred the mixed types.

The two types of grasslands found throughout the Black Hills and Bear Lodge Mountains have been described by Pase and Thilenius (1968). The mixed prairie type, dominated by *Stipa comata*, *Bouteloua gracilis*, *Andropogon scoparius*, *A. gerardii*, and *Agropyron smithii*, was found on soils developed from sandstone or limestone and on shallower soils than the bluegrass type. The bluegrass type was dominated almost exclusively by *Poa pratensis*, although *P. compressa* was dominant in one area. *Phleum pratense* was also abundant in this type. The bluegrass type was generally associated with streams or at higher elevations on soils derived in place from sedimentary and metamorphic materials.

Methods

Field Sampling

Twenty-eight aspen stands were sampled throughout the Black Hills and Bear Lodge Mountains (fig. 3). Sample stands were selected in a stratified random manner to distribute inventoried stands throughout the study area. Physical site characteristics described for each stand included aspect, angle and position of slope, elevation, land form, relief, and presence or absence of disturbing factors such as fire, grazing, logging, and mining.

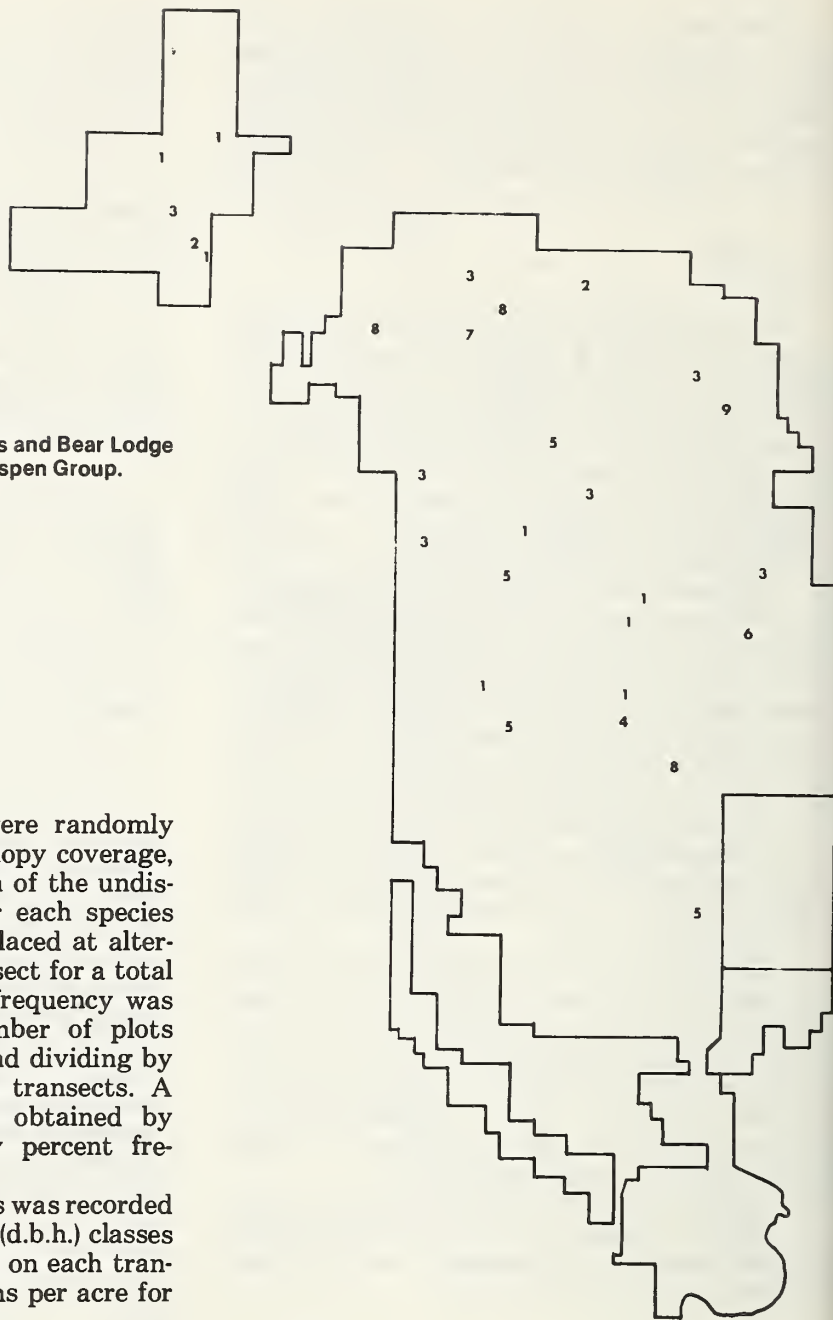


Figure 3.—Location of stands in Black Hills and Bear Lodge Mountains. Number corresponds to Aspen Group.

Two 50-foot line transects were randomly established within each stand. Canopy coverage, interpreted as a vertical projection of the undisturbed canopy, was estimated for each species occurring in a 1-foot-square plot placed at alternate foot intervals along each transect for a total of 25 plots per transect. Percent frequency was determined by counting the number of plots within which a species occurred, and dividing by the total number of plots in the transects. A cover-frequency index (CFI) was obtained by multiplying the percent cover by percent frequency for each species.

Density (stems per plot) of trees was recorded by 4-inch diameter at breast height (d.b.h.) classes on five 10- by 10-foot plots located on each transect. Counts were adjusted to stems per acre for analysis.

After vegetation sampling was completed, a soil pit was excavated near the center of the stand and the soil described according to standards established by the U.S. Soil Survey Staff (1951). Geological formations were determined for each stand by reference to Darton's (1921) geological map of the Black Hills, and from material collected from subsurface horizons (C and R).

Approximate stand ages were obtained by cross sectioning or core sampling (depending on tree size) the five largest trees in the stand and averaging these ages.

Analytical Methods

To identify similar aspen stands, we slightly modified the method Thilenius (1972) used to classify *Pinus ponderosa* units in the Black Hills.

The synecological units of aspen communities were determined by grouping the sample plots into sets whose members were similar in vegetation, soil, and site attributes. Table 1 gives the characteristics used, their units of measurement, and method of coding.

Table 1.—Attribute coding for computer analysis (adapted from Thilenius 1972)

A. Vegetation

1. Density of overstory trees (by species and d.b.h. class) in percent.
2. CFI¹ of large shrubs (by species) in percent.
3. CFI of small shrubs, grasses, sedges and forbs (by species) in percent.

B. Soil

1. Number of mineral horizons present.
2. Total depth in inches.
3. Thickness of the O₁ horizon (litter) in inches.
4. Thickness of the O₂ horizon (humus) in inches.
5. Thickness of the A₁ horizon in inches.
6. Hue of the A₁ horizon, scaled to give the highest value to red and the lowest to yellow.
 - a. 10R = 64
 - b. 2.5 YR = 32
 - c. 5 YR = 16
 - d. 7.5 YR = 8
 - e. 10 YR = 4
 - f. 2.5 Y = 2
 - g. 5 Y = 1
7. pH of the A₁ horizon to the nearest 0.1 pH unit (electrometrically determined).
8. Texture of the A₁ horizon specified by a particle size "ratio-of-10" derived by rounding off the average percentage of sand (2.0 mm–0.05 mm), silt (0.05 mm–0.002 mm), and clay (<0.002 mm) in the 12 textural classes given in the Soil Survey Manual (1951). The sum of the numerals equals 10 in all classes.
 - a. Sand = 910
 - b. Loamy sand = 811
 - c. Sandy clay loam = 712
 - d. Sandy loam = 541
 - e. Sandy clay = 514
 - f. Loam = 442
 - g. Clay loam = 334
 - h. Silt = 181
 - i. Silt loam = 172
 - j. Silty clay loam = 163
 - k. Silty clay = 154
 - l. Clay = 118
9. Percentage of coarse fragments (+2 mm) in the A₁ horizon.
10. Effervescence with HCl of the A₁ horizon.
 - a. Violent 8
 - b. Strong 4
 - c. Slight 2
11. Thickness of the A₂ horizon (eluviation zone) in inches.
12. Hue of the A₂ horizon (see item 6).
13. pH of the A₂ horizon (see item 7).
14. Texture of the A₂ horizon (see item 8).
15. Percentage of coarse fragments in the A₂ horizon.
16. Effervescence with HCl of the A₂ horizon (see item 10).
17. Thickness of the B₂ horizon (illuviation zone) in inches.
18. Hue of the B₂ horizon (see item 6).
19. pH of the B₂ horizon (see item 7).
20. Texture of the B₂ horizon (see item 8).
21. Percentage of coarse fragments in the B₂ horizon.
22. Effervescence of the B₂ horizon (see item 10).
23. Hue of the C horizon (see item 6).
24. pH of the C horizon (see item 7).
25. Texture of the C horizon (see item 8).
26. Percentage of coarse fragments of the C horizon.
27. Effervescence of the C horizon (see item 10).

C. Site

1. Slope aspect in degrees from true north.
2. Slope angle in percent.
3. Elevation in feet.
4. Position in percentage of slope below the nearest ridge.
5. Macrorelief of general area.
 - a. Level = 0
 - b. Undulating = 5
 - c. Rolling = 15
 - d. Hilly = 30
 - e. Steep = 50
6. Microrelief in immediate vicinity of plot.
 - a. Concave = 1
 - b. Flat = 2
 - c. Convex = 3
7. Percentage of ground covered by rocks.
8. Percentage of ground covered by litter.
9. Percentage of bare ground.

¹CFI = Cover-frequency index = product of percent cover and percent frequency.

Results

The dendrogram depicted in figure 4 is arranged so that the more xeric groups are located on the left and the mesic groups on the right. The percent similarity level $K = 60$ was an arbitrary choice, based on the assumption that this level delineated a reasonable number of functional classification groups. A lower value of K would have given fewer groups, but within-group heterogeneity would have been greater. Higher values of K would create more homogeneous groups, but would increase the number of groups to a point where the classification would be meaningless, particularly from the resource management standpoint.

In the following descriptions of each group, the AG's are identified by the dominant overstory species (underlined data in table 2) followed by the dominant shrub, grass, and forb species (table 3). If a CFI value did not reach 100 (table 3) for any species in any one of the plant categories in the understory strata, that category was eliminated from the group name. Constancy, as used in these tables, is defined as the occurrence of species in equal samples over the range of the type. Like frequency, it is a measure of ubiquity, but ubiquity among a series of stands rather than among plots in a single stand (Daubenmire 1968).

A general discussion of characteristics common to all *Populus tremuloides* stands follows descriptions of the AG's.

Table 2.--Percent constancy (Const.) and average density (AvD) of overstory species in the Aspen Groups (AG) defined at $K \geq 60$, with number of stands (n); underlined data indicate dominant species

Species and size class	AG-1 (n=8)		AG-2 (n=2)		AG-3 (n=7)		AG-4 (n=1) ¹	AG-5 (n=4)		AG-6 (n=1) ¹	AG-7 (n=1) ¹	AG-8 (n=3)		AG-9 (n=1) ¹
	Const.	AvD	Const.	AvD	Const.	AvD	AvD	Const.	AvD	AvD	AvD	Const.	AvD	AvD
<i>Populus tremuloides</i>														
<4 inches d.b.h.	100	3953	100	1939	100	372	697	100	819	218	-	-	-	174
4- 8 inches d.b.h.	63	93	100	89	100	459	-	100	316	610	1220	100	479	305
8-12 inches d.b.h.	-	-	-	-	14	19	-	-	-	-	-	63	73	-
>12 inches d.b.h.	-	-	-	-	-	-	174	-	-	-	-	-	-	-
<i>Betula papyrifera</i>														
<4 inches d.b.h.	13	38	-	-	43	118	-	-	-	-	-	67	102	44
4- 8 inches d.b.h.	-	-	-	-	43	75	-	-	-	-	-	-	-	-
<i>Pinus ponderosa</i>														
<4 inches d.b.h.	13	6	50	22	57	37	44	25	55	131	-	-	-	-
<i>Quercus macrocarpa</i>														
<4 inches d.b.h.	13	11	-	-	-	-	-	-	-	392	-	-	-	44
<i>Picea glauca</i>														
<4 inches d.b.h.	25	16	-	-	57	62	-	-	-	-	-	-	-	-
<i>Ostrya virginiana</i>														
<4 inches d.b.h.	-	-	-	-	-	-	-	-	-	-	-	-	-	871
<i>Amelanchier alnifolia</i>														
<4 inches d.b.h.	13	16	-	-	-	-	332	-	-	6	-	67	115	6
<i>Corylus cornuta</i>														
<4 inches d.b.h.	-	-	-	-	-	-	-	-	-	-	-	100	793	-
<i>Prunus virginiana</i>														
<4 inches d.b.h.	13	16	-	-	-	-	12	-	-	2	-	33	5	-
<i>Salix</i> spp.														
<4 inches d.b.h.	-	-	-	-	14	6	87	-	-	-	-	-	-	-

¹Constancy eliminated from AG-4, AG-6, AG-7, and AG-9 because each is represented by a single stand.

Table 3.--Percent constancy (Const.) and cover-frequency index (CFI) of major understory species in the Aspen Groups (AG) defined at K₂>60, with number of stands (n); underlined data indicate dominant species

Species	AG-1 (n=8)		AG-2 (n=2)		AG-3 (n=7)		AG-4 (n=1) ¹	AG-5 (n=4)		AG-6 (n=1) ¹	AG-7 (n=1) ¹	AG-8 (n=3)		AG-9 (n=1) ¹
	Const.	CFI	Const.	CFI	Const.	CFI	CFI	Const.	CFI	CFI	CFI	Const.	CFI	CFI
SHRUBS (<4 feet)														
<i>Amelanchier alnifolia</i>	88	8	50	144	43	24	228	50	32	784	26	67	24	170
<i>Arctostaphylos uva-ursi</i>	75	30	-	-	43	3	-	25	11	10	-	-	-	-
<i>Ceanothus velutinus</i>	25	55	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cornus canadensis</i>	-	-	-	-	-	-	-	-	-	-	-	33	16	-
<i>Corylus cornuta</i>	38	4	50	1	14	40	-	-	-	-	162	100	4617	-
<i>Juniperus communis</i>	25	1	-	-	14	4	-	50	10	-	-	-	-	-
<i>Mahonia repens</i>	63	259	100	472	100	132	-	50	4	-	114	67	42	512
<i>Ostrya virginiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	5632
<i>Physocarpus monogynus</i>	13	1	-	-	14	36	-	-	-	1568	-	-	-	-
<i>Populus tremuloides</i>	50	1	50	2	29	14	-	50	5	1	1	100	7	8
<i>Prunus virginiana</i>	50	4	50	24	29	1	216	50	1	494	4	67	6	16
<i>Ribes missouriense</i>	-	-	-	-	-	-	756	-	-	14	40	33	1	28
<i>Rosa woodsii</i>	88	81	100	128	100	46	414	100	250	48	312	67	3	-
<i>Rubus parviflorus</i>	13	2	-	-	-	-	-	-	-	-	4232	67	90	-
<i>Rubus strigosus</i>	38	5	50	2	14	1	36	50	192	203	-	33	52	2
<i>Shepherdia canadensis</i>	88	22	-	-	29	1	-	-	-	56	-	-	-	-
<i>Spiraea lucida</i>	88	276	100	84	57	148	10	25	7	324	102	100	36	120
<i>Symphoricarpos albus</i>	88	152	100	590	100	114	288	100	70	576	780	100	105	434
<i>Vaccinium scoparium</i>	-	-	-	-	14	10	-	-	-	-	-	-	-	-
GRAMINOIDS														
<i>Agropyron subsecundum</i>	88	31	100	9	29	6	-	50	9	-	350	67	3	-
<i>Agrostis exarata</i>	13	3	-	-	-	-	-	50	3	3	-	33	1	-
<i>Bromus inermis</i>	-	-	-	-	-	-	1	25	3	8	6	33	1	3
<i>Bromus marginatus</i>	13	1	50	1	57	8	-	50	12	-	-	67	21	-
<i>Carex concinna</i>	50	1	50	6	14	1	-	50	30	-	-	-	-	-
<i>Carex foena</i>	13	5	-	-	71	28	12	75	14	-	-	33	12	9
<i>Danthonia intermedia</i>	88	54	50	2	14	1	-	75	100	12	1	-	-	-
<i>Danthonia spicata</i>	38	14	-	-	-	-	-	25	3	-	-	-	-	-
<i>Elymus canadensis</i>	13	2	50	1	71	27	2	25	112	190	16	33	4	-
<i>Elymus innovatus</i>	50	80	-	-	57	54	-	-	-	-	-	-	-	-
<i>Oryzopsis asperifolia</i>	75	14	100	15	100	102	689	100	13	60	1	100	27	792
<i>Poa pratensis</i>	75	14	50	5	71	21	1	100	2490	320	-	-	-	5
<i>Schizachne purpurascens</i>	-	-	-	-	-	-	-	25	1	-	-	67	2	-
<i>Stipa columbiana</i>	-	-	-	-	14	3	544	50	80	2	-	-	-	-
FORBS														
<i>Achillea millefolium</i>	-	-	50	6	57	5	2	100	80	10	-	-	-	3
<i>Actaea rubra</i>	-	-	-	-	-	-	-	25	1	-	2	67	11	600
<i>Agoseris glauca</i>	25	2	50	1	-	-	-	-	-	1	-	-	-	-
<i>Anaphalis margaritacea</i>	13	4	-	-	14	7	-	25	7	-	140	-	-	-
<i>Apocynum androsaemifolium</i>	75	15	100	42	29	3	1	50	1	8	2	-	-	12
<i>Aralia nudicaulis</i>	25	1	-	-	43	5	4	-	-	22	1560	100	826	-
<i>Aster laevis</i>	83	111	100	168	100	81	1482	100	152	76	120	100	120	220
<i>Astragalus alpinus</i>	50	26	-	-	29	15	2	25	28	-	-	-	-	-
<i>Astragalus tenellus</i>	25	18	-	-	14	5	-	-	-	-	-	-	-	-
<i>Circaea lutetiana</i>	13	T	50	1	29	3	-	-	-	-	1	33	2	16
<i>Fragaria ovalis</i>	63	22	50	18	71	22	76	50	26	1	3	67	2	24
<i>Fragaria vesca</i>	13	1	-	-	-	-	16	75	10	4	1	33	3	6
<i>Galium boreale</i>	75	21	100	7	71	28	50	100	30	24	5	67	6	4
<i>Galium triflorum</i>	-	-	-	-	-	-	-	25	3	-	-	33	13	5
<i>Geranium richardsonii</i>	25	2	-	-	86	3	-	50	3	-	-	-	-	-
<i>Heracleum lanatum</i>	-	-	-	-	14	T	-	25	6	-	-	33	9	-
<i>Iris missouriensis</i>	13	T	-	-	-	-	-	50	24	-	-	-	-	-
<i>Lathyrus ochroleucus</i>	100	364	100	800	71	80	240	100	66	144	1232	100	38	80
<i>Maianthemum canadense</i>	-	-	-	-	29	2	384	-	-	6	7	100	255	16
<i>Monarda fistulosa</i>	75	60	100	52	29	15	10	100	140	48	138	-	-	1
<i>Osmorhiza obtusa</i>	25	3	50	56	29	3	-	25	1	-	-	100	82	5
<i>Pteridium aquilinum</i>	13	1	100	5915	29	28	-	-	-	-	-	67	2	-
<i>Pyrola secunda</i>	-	-	-	-	-	-	28	-	-	-	1	33	1	2
<i>Sanicula marilandica</i>	50	1	50	152	57	2	6	75	60	136	-	67	16	20
<i>Smilacina stellata</i>	25	6	100	68	43	1	80	100	16	156	3	100	19	184
<i>Solidago spp.</i>	50	2	-	-	29	2	-	-	-	1	-	-	-	-
<i>Taraxacum officinale</i>	38	3	50	T	86	2	-	100	5	-	-	67	T	T
<i>Thalictrum venulosum</i>	25	1	100	16	71	36	84	100	72	-	360	100	69	24
<i>Trifolium repens</i>	13	T	-	-	50	12	-	100	742	-	-	-	-	-
<i>Vicia americana</i>	83	32	50	3	57	2	240	75	4	1	72	67	140	44

¹Constancy eliminated from AG-4, AG-6, AG-7, and AG-9 because each is represented by a single stand.

AG-1: *Populus tremuloides*/*Spiraea lucida*/*Lathyrus ochroleucus* (fig. 5).

This group, represented by eight stands, was characterized by a very high average density of small (less than 4 inches d.b.h.) *Populus tremuloides* per acre ($\approx 4,000$). *Mahonia repens* was found in many of the represented stands, and had a CFI almost equaling *Spiraea lucida*. *Aster laevis* was second to *Lathyrus ochroleucus* in the forb category but did not occur in all stands. Grasses were relatively unimportant although *Danthonia intermedia* and *Elymus innovatus* did assume local importance. Average number of species in this AG was 32, with a mean percentage canopy cover of 126.

Aspens in this AG were young, with an average age of 28 years. The fire history was fairly well documented. Five of the eight stands were located on sites that were burned 31 or 39 years ago, according to forest fire records of the Black Hills National Forest. No dated records were available for the remaining three stands, but signs of forest fire were present in two. There was no evidence that the remaining stand, which occupied the periphery of an upland meadow, had ever been burned.

All stands in AG-1 were found on north-facing slopes, and varied in elevation from 5,075 to 6,450 feet. All were located between the 19- and 24- inch isohyets. These stands were not confined to any geographic pattern or type location, but were scattered from the central Bear Lodge Mountains southeastward into the central Black Hills.

Soils were derived from various parent materials including metamorphic slate schists, and sedimentary limestones, sandstones, and sandstone-chert conglomerates. Soils were relatively shallow, averaging 23 inches (range: 19 to 50 inches), and rocky throughout. Profile development was variable, exhibiting an A/C/R sequence on three recently burned stands and $A_1/B_{2t}/C/R$ on other stands. One of the older, burned stands and the unburned stand, with soil depths of 34 and 50 inches, respectively, had well-developed $A_1/A_2/B_1/B_2/C/R$ profiles.



Figure 5.—AG-1:
Populus tremuloides/*Spiraea lucida*/*Lathyrus ochroleucus*.

AG-2: *Populus tremuloides* / *Symphoricarpos albus*/*Pteridium aquilinum* (fig. 6).

AG-2, represented by only two stands, was easily recognized by the abundance of *Pteridium aquilinum*, which formed a distinct and virtually solid layer in the understory. *Populus tremuloides* were small (less than 4 inches d.b.h.), and had only half the density of those in the preceding AG. The shrubs *Symphoricarpos albus*, *Mahonia repens*, and *Rosa woodsii* were well represented in the understory, as was the forb *Lathyrus ochroleucus*. Grasses were relatively unimportant in this group. There were 27 and 34 species present in the two stands, resulting in total canopy covers of 145 and 203 percent.

The ages and fire history of the stands in this AG appear similar to the preceding group. The average age was 20 years, and both were burned in the 1930's.

These stands were located on north and south-eastern exposures but with very little slope (5° to 8°). Again, stand locations were widely separated, one in the central Bear Lodge and the other in the north-central Black Hills. Elevations ranged from 5,250 to 5,675 feet; precipitation approximated 20 and 25 inches, respectively.

Soils of both stands originated from Tertiary igneous parent material, were rocky throughout, and weakly developed. The two stands had A₁/C/R and A₁/B_{2t}/C/R profile sequences and respective depths of 19 and 27 inches.



Figure 6.—AG-2:
Populus tremuloides / *Symphoricarpos albus* / *Pteridium aquilinum*.



Figure 7.—AG-3:
Populus tremuloides/*Mahonia repens*/*Oryzopsis asperifolia*.

AG-3: *Populus tremuloides*/*Mahonia repens*/*Oryzopsis asperifolia* (fig. 7).

Seven stands were included in this AG. The vegetative characteristics were not as clearly delineated as in the two preceding groups. *Populus tremuloides* was represented by larger and fewer trees (4- to 8-inch d.b.h. class, 459 trees per acre). The smaller class (less than 4 inches d.b.h.) occurred with 100 percent constancy but with fewer trees (372 per acre). Conifers were invading all stands, either *Pinus ponderosa* or *Picea glauca*, and in one case both species. *Rosa woodsii* and *Symphoricarpos albus*, like *Mahonia repens*, were found in all seven stands but had much lower CFI values. Grasses were not important in this AG except for the title species *Oryzopsis asperifolia*. Forbs, although well represented in numbers of species, had low constancy and CFI values. Only *Aster laevis* was found in all stands. An average of 33 species occurred; mean total percent canopy cover was 128.

Stand age of this AG averaged 61 years and ranged from 48 to 75. Fire histories are reasonably evident for the sites within the group. Three areas were burned 59, 71, and 77 years ago. No definite records are available on the other four sites, but all showed evidence of having been burned.

As with the preceding AG, the stands in this group did not exhibit any geographical, elevational, or precipitational relationships. They were distributed from the central Bear Lodge Mountains southeastward into the Black Hills just west of Rapid City. Elevations ranged from 4,750 to 6,525 feet. Two stands were located between the 20- and 21-inch isohyets, one on the 23-inch isohyet, and the rest scattered between.

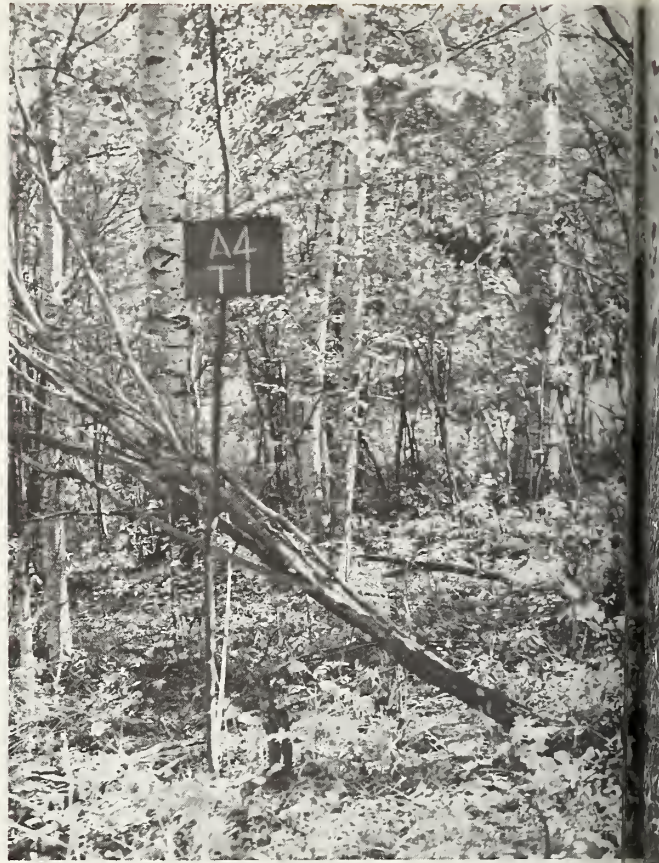
Soils of stands in AG-3 were derived from limestones or the sandstone-shale-limestone conglomerates of the Deadwood Formation. All exhibited well-developed profiles, typically $A_1/A_2/A_3/B_{2t}/C/R$ and $A_1/A_2/B_{2t}/C/R$, although one stand did have a weakly developed $A_1/B/C/R$. Soil depths varied from 19 to 49 inches and averaged 30 inches.

AG-4: *Populus tremuloides*/*Ribes missouriense*/*Oryzopsis asperifolia* / *Aster laevis* (fig. 8).

AG-4 was represented by a single stand that contained the largest individual specimens of *Populus tremuloides* found in any of the study areas. Trees in the 12- to 16-inch d.b.h. class were present at a density of 174 per acre. *Populus tremuloides* stems with less than 4 inches d.b.h. also occurred on this site (700 trees per acre). There were no intermediate size classes on the sample transects. Tall stems (over 4 feet high) of *Amelanchier alnifolia* were also present (332 per acre). *Rosa woodsii* was an abundant understory shrub along with *Ribes missouriense*. *Stipa columbiana* almost equaled *Oryzopsis asperifolia* in dominance, whereas *Aster laevis* surpassed all other forbs in importance. Forty-five species were recorded within this stand, with a total canopy cover of 167 percent.

The stand was located at 5,800 feet within the 19-inch isohyet. There was no record or any evidence of fire in this specific area, although a 1931 fire burned a large tract less than ¼ mile north. The age of this stand (54 years) indicates that the area had to have burned about 20 years previous to 1931, if at all.

Soils were developed from colluvial metamorphic slate material. Because large boulders and fragmented rocks of varying sizes were common under a soil mantle of varying depth (4 to 35 inches), a soil profile was difficult to obtain. In larger fissures between boulders, soils appeared to be well developed with a horizon sequence of A₁/A₂/B₁/B₂/C/R.



**Figure 8.—AG-4:
Populus tremuloides / *Ribes missouriense* / *Oryzopsis asperifolia* / *Aster laevis*.**



Figure 9.—AG-5:
Populus tremuloides / *Rosa woodsii* / *Poa pratensis* / *Trifolium repens*.

AG-5: *Populus tremuloides*/*Rosa woodsii*/*Poa pratensis*/*Trifolium repens* (fig. 9).

AG-5, represented by four stands, contained two size classes of trees, less than 4 inches d.b.h. and 4 to 8 inches d.b.h., all *Populus tremuloides*. One stand also contained *Pinus ponderosa* saplings. This AG was characterized by a dense growth of the rhizomatous grass *Poa pratensis* and the stoloniferous forb *Trifolium repens*. *Rosa woodsii* was the only shrub considered abundant throughout the AG, although *Symphoricarpos albus* was also found in all stands. *Aster laevis* and *Monarda fistulosa* were other forbs that had a constancy of 100 percent, but neither was as prevalent as *Trifolium repens*. The four stands had an average total canopy cover of 140 percent, and contained a mean of 39 plant species.

Three of the four stands were located on north-facing slopes, but the oldest had an eastern exposure. Ages of aspen trees in the stands varied: in three stands the aspen were only 15, 18, and 19 years old. Two of these had been burned in the same wildfire in September 1931. The other contained remnants of burned logs indicating an unrecorded fire sometime in the past. The remaining stand, where the aspen averaged 79 years old, did not show any evidence of being burned. This oldest stand, the southernmost sampled, was found at 5,125 feet along a streambank within the 19-inch isohyet. The younger stands were located in the central and northern Black Hills, from 6,400 to 6,850 feet and between the 21- and 23-inch isohyets.

Soil depths averaged 32 inches. The oldest stand had the deepest soil (44 inches), which exhibited a poorly developed $A_1/B_{2t}/C/R$ profile and was developed from limestone parent material. The other three stands had more strongly developed profiles and exhibited a distinct A_2 horizon. These were developed from limestone, limestone-sandstone conglomerates, and quartzitic schist.

AG-6: *Populus tremuloides*/*Physocarpus monogynous*/*Poa pratensis*/*Smilacina stellata* (fig. 10).

AG-6 was represented by a single stand in a narrow, V-shaped draw on the east side of the central Black Hills, at an elevation of 4,750 feet near the 20-inch isohyet. It is related to AG-5 in that *Poa pratensis* was predominant in the herbaceous understory, but differs because *Trifolium repens* was absent and also because *Physocarpus monogynous*, a medium-sized shrub, formed a distinct stratum. The size class distribution of *Populus tremuloides* was also reversed, compared with AG-5. AG-6 contained a much higher proportion of *Quercus macrocarpa* in the overstory than any other AG. *Elymus canadensis* was another important grass, and the most numerous forb was *Smilacina stellata*. *Sanicula marilandica* and *Lathyrus ochroleucus* were also well represented. The 49 species found in this stand contributed a total canopy cover of 140 percent.

The fire history of the area in which this stand was located is somewhat obscure. Records indicate the locale was burned in the early 1890's. Evidence of a past fire was found within the studied stand, but we could not determine whether it was left by the recorded burn or a later, unrecorded fire. The oldest trees in the stand were only 27 years.

The soil had an A₁/B_{2t}/C/R horizon sequence and was only 17 inches deep. Parent materials were colluvial slate-schists which occurred "on edge" and as large plates scattered throughout the profile.

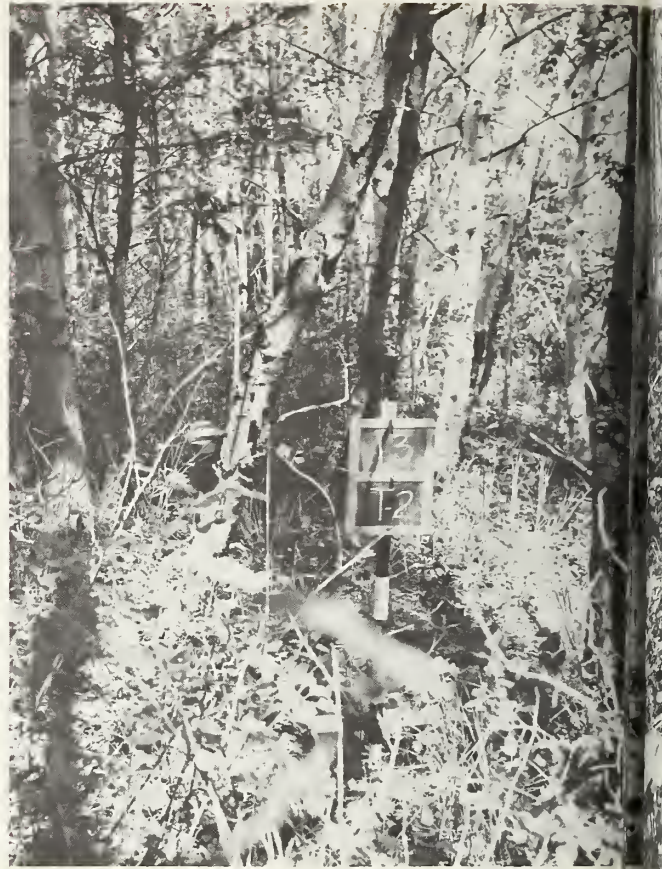


Figure 10.—AG-6:
Populus tremuloides / *Physocarpus monogynous* / *Poa pratensis* / *Smilacina stellata*.



AG-7: *Populus tremuloides*/*Rubus parviflorus*/
Agropyron subsecundum/*Aralia nudicaulis*
(fig. 11).

AG-7 was represented by a single stand located at 5,600 feet in the northwestern part of the Black Hills. All *Populus tremuloides* were in the 4- to 8-inch d.b.h. class; no saplings and only very few sprouts were noted. The understory was characterized by an abundance of the shrub *Rubus parviflorus*. Grasses again were relatively unimportant, and were represented primarily by one species—*Agropyron subsecundum*. Forbs were abundant; the most important species, *Aralia nudicaulis*, was followed closely by *Lathyrus ochroleucus*. Forty-five species were found in this stand, which had a total percent canopy cover of 152.

Although fire records indicate this area was extensively burned in 1890, the oldest *Populus tremuloides* present were only 29 years. No evidence of fires that might have been more recent was found.

Soil was derived in place from limestone parent materials, and exhibited a profile sequence of $A_1/B_{2t}/C/R$.

Figure 11.—AG-7:
Populus tremuloides / *Rubus parviflorus* / *Agropyron sub-*
secundum / *Aralia nudicaulis*.

AG-8: *Populus tremuloides*/*Corylus cornuta*/*Aralia nudicaulis* (fig. 12).

Three stands were classified in AG-8. Two were located in the northern Black Hills at 5,750 and 6,000 feet and the other, 2 miles northwest of Harney Peak in Palmer Gulch at 5,400 feet. This AG was characterized by a distinct shrub understory of *Corylus cornuta*. Other shrubs and graminoids were scarce, although *Spiraea lucida*, *Symphoricarpos alba*, and *Oryzopsis asperifolia* occurred in all three stands. Only two forbs were important; *Aralia nudicaulis* had the highest CFI, followed by *Maianthemum canadense*. The three stands contained an average of only 35 species, but had a mean total canopy cover of 177 percent.

The aspen in these three stands were among the oldest sampled: 77, 78, and 98 years. All stands had evidences of past fires, and two were located in areas that were recorded as having burned before the turn of the century, about 80 and over 90 years ago. *Populus tremuloides* was present in two size classes: 4 to 8 inches and 8 to 12 inches d.b.h., 479 and 73 trees per acre, respectively. No saplings (less than 4 inches d.b.h.) were noted, and only a very few sprouts were found. The two coniferous species considered climax on forest sites, *Pinus ponderosa* and *Picea glauca*, were not present. The fire evidences, however, were scorched pitch stumps, presumably of *Pinus ponderosa*.

Soils in the AG were derived from quartzitic schists and Tertiary igneous parent material. Soils were well developed with a distinct A₂, although a transitional AC horizon appeared in two stands as compared to a B₁/B₂ sequence in the other. Soils information was difficult to obtain in all stands in this AG because of water seeping into pits.



Figure 12.—AG-8:
***Populus tremuloides* / *Corylus cornuta* / *Aralia nudicaulis*.**



Figure 13.—AG-9:
Populus tremuloides / *Ostrya virginiana* / *Oryzopsis asperifolia* / *Aralia nudicaulis*.

AG-9: *Populus tremuloides* / *Ostrya virginiana* / *Oryzopsis asperifolia* / *Aralia nudicaulis* (fig. 13).

This most mesic AG was represented by one stand located in the northeastern Black Hills at an elevation of 4,550 feet. The stand, positioned on the lower slopes and bottom of a deep draw, was one of two that had a southern exposure. *Populus tremuloides*, although not the most numerous tree in the stand, did maintain dominance because of its multilayered canopy. Over 300 trees per acre in the 4- to 8-inch d.b.h. class were present, along with 174 in the smaller class (less than 4 inches d.b.h.). *Ostrya virginiana* was the predominant subordinate tree, with 871 trees per acre, all in the smaller class (less than 4 inches d.b.h.). *O. virginiana* was also the predominant species in the shrub class, as it formed a variable layer throughout the stand. *Mahonia repens* and *Symphoricarpos albus* were the most abundant shrubs in the lowest layer. Graminoids, with the notable exception of *Oryzopsis asperifolia*, were almost absent from the AG. *Actaea rubra* was the predominant forb, and *Aster laevis* and *Smilacina stellata* were well represented. The 47 species found in this stand contributed a total percent canopy cover of 164.

There were very scant evidences of a past fire in a *Pinus ponderosa* type on the more xeric slopes and ridges around the study site, but none could be found within the stand. The oldest *Populus tremuloides* were over 70 years, and presumably any indications of past fires could have been obscured or eliminated by the moist conditions within the stand.

Soils were 40 inches deep, well developed, and were derived from limestone parent material. The profile exhibited an $A_1/A_2/A_3/B_{2t}/C/R$ sequence.

Discussion

Site Characteristics

Aspen stands in the Black Hills and Bear Lodge Mountains were found at elevations ranging from about 4,000 to 7,000 feet. Sampled stands varied from 4,550 to 6,850 feet. These stands did not exhibit the elevation-exposure relationships found in aspen stands in the Rocky Mountains. Reed (1971), working in the Wind River Mountains, Wyoming, found that the aspen type extended to the lowest elevations (7,500 to 8,200 feet) on northern exposures where conditions were more moist and cooler. At middle elevations (8,200 to 8,900 feet) aspen occurred in relatively similar proportions on all slopes. About 95 percent of the aspen stands at higher elevations (8,900 to 10,000 feet) were located on east-, west-, or south-facing slopes. Severson (1964) studied aspen in south-central Wyoming and noted a similar pattern. The aspen type in the Black Hills and Bear Lodge Mountains, however, was restricted almost entirely to slopes with northern exposures. Only 2 of the 28 stands sampled had southern exposures (between 90° and 270°). One, facing due south, was the most mesic because of its topographic location in the bottom of a deep, steep-sided, narrow draw (AG-9). The other (AG-2), with a southeastern exposure (135°), was a relatively xeric stand located at 5,670 feet. All other study areas had northerly exposures varying from 310° to 70°.

Although the dendrogram (see fig. 4) describes a xeric to mesic transition of aspen stands, it must be remembered that this trend is relative within the type. All of the aspen stands existed because of favorable moisture conditions. These included—besides the northern exposure—concave slopes, wet subirrigated areas (particularly at limestone-metamorphic schist interfaces), snow-pack areas, and deep, steep-sided draws that, regardless of exposure, permitted so little direct sunlight the effect was similar to a northern exposure. When comparing site characteristics of Black Hills aspen with those of the Rocky Mountain areas, only aspen sites found at lower elevations are comparable (for example, northern exposures). The Black Hills and Bear Lodge Mountains are not high enough to permit development of aspen stands on other exposures as occurs at middle and higher elevations in the Rocky Mountains.

Site locations indicate that aspen in the Black Hills and Bear Lodge Mountains is on the edge of its normal range. Beetle (1961) has suggested that such peripheral stands can be recognized

by their confinement to mesic situations, short-lived communities, unstable margins, and because they are often dwarf communities compared to development elsewhere.

Soils

Although a general description of soil characteristics was given for each Aspen Group, it should be noted that soils are poorly correlated with vegetation in aspen stands. This indicates that the history of disturbance, including seral age, may be more important than soils in determining plant composition. A similar lack of correlation between vegetation and soil profile descriptions has been found in Washington and northern Idaho (Daubenmire and Daubenmire 1968, Daubenmire 1970) and in northern Minnesota.²

Soils under aspen stands in the Black Hills and Bear Lodge Mountains can be discussed more appropriately by dividing them into three basic groups based on development of horizons. These soil groups do not correspond to the Aspen Groups previously described, and will be identified as I, II, and III.

The only feature consistent through all groups was the presence of an A₁ horizon with a granular structure, which occurred in all 28 profiles examined and varied in depth from 1 to 8 inches. Radeke and Weston (1963), in their description of the wooded soils of the Black Hills, included a group with a well-developed mineral-organic A₁ horizon. They further noted that this group characteristically occurred at higher elevations and on sites that were relatively cooler and more moist, which, as previously discussed, were site descriptions typical of where aspens were found. Reed (1971) also noted an A₁ in all *Populus tremuloides*-*Symphoricarpos oreophilis* stands studied in the Wind River Mountains, Wyoming.

Soil group I, the largest of the three, was found in 15 stands and had a well-developed A₂ which, characteristically, was lighter in color than the overlying thin A₁ (2 inches deep) or underlying B horizons. The A₂ varied in depth from 2.5 to 17 inches and averaged 5.8 inches. B horizons were variable; some were only identified as B (seven stands), but a definite B_{2t} was noted in some and a B₁/B₂ sequence identified others. The C horizons in this group varied from 5 to 16 inches in depth and averaged only 10 inches, the shal-

²Personal communication from L. F. Ohmann, North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, Minn.

lowest C horizon of the three groups. Overall, however, these soils were the deepest, averaging 31 inches and ranging from 18 to 49 inches.

The second group (II), with eight stands represented, had a slightly thicker A_1 (3 inches), but no A_2 . Four stands had a recognizable B_{2c} but the other four contained mineral horizons that could only be identified as B. The C horizons were slightly thicker than in the preceding group, averaging 12 inches. Soil depths were slightly shallower than the preceding group, with a mean of 29 inches.

The third group (III) had a thick A_1 (5 inches) but no A_2 or B horizons. The C horizon was quite thick (17 inches). This group had the shallowest soils, with an average depth of 23 inches.

Groups I and II had soil textures ranging from granular loams to silty loams to clay loams in the surface horizons (A_1/A_2 or just the A_1) which graded into heavy-textured angular blocky clays in the C horizons, a natural feature of well-developed soils. Group III, however, contained granular silty clays or granular clays in both the A_1 and C horizons. No change in structure or texture was observed between horizons.

Textures of Black Hills aspen soils were somewhat finer than aspen soils in other areas. Severson (1964) noted that soils under aspen in Wyoming were predominantly sandy loams, loams, or silty loams. Hoff (1957), in Colorado, found that aspen soils were "...invariably sandy loams." Other studies in Colorado and northern New Mexico likewise found sandy loam A horizons in a large majority of aspen stands, but also found loamy sand, loam, and even clay loam A horizons.³

Organic horizons were similar in all three groups. The undecomposed organic matter (O_1) was 0.6, 0.9, and 0.8 inch deep for groups I, II, and III, respectively, and the decomposed organic matter (O_2) was 1.1, 1.0, and 0.9 inches deep. These are somewhat deeper than the 0.4- to 1.2-inch total organic matter depths reported by Reed (1971) in the Wind River Mountains of Wyoming.

Soil pH varied only slightly between horizons and between groups. Black Hills aspen soils were slightly acidic, with a mean pH of 6.3 ± 0.1 over all horizons in all groups. One stand had pH values of 4.5, 5.0, 5.0, and 4.9 in the A_1 , A_2 , B, and C horizons, respectively. This stand was located adjacent to a drainage which contained

extensive deposits of bog iron, which are characteristically very acidic. There was a tendency toward higher pH levels in the lower horizons in group I. Here, the mean pH of the A_1 was 6.1 as compared to 6.6 in the C. The same tendency was noted in groups II and III, but to a lesser degree. The pH of group II soils increased from 6.2 to 6.4, whereas the A_1 and C horizons in group III had pH's of 5.9 and 6.1. The pH of the organic-mineral A_1 in all groups was 6.1 ± 0.2 . Severson (1964) reported the pH in the top 4 inches of mineral soil under aspen to be 6.2 ± 0.1 in south-central Wyoming, and Reed (1971), working in the Wind River Mountains of the same State, found soil pH to range from 5.9 to 7.5 with a mean of 6.4 ± 0.2 . Higher pH values, 6.6 to 7.4, were reported by Hoff (1957) from the Rocky Mountains of Colorado.

The pH values of the C horizon in soils derived from limestone parent materials were expectedly higher (6.8) than those derived from slate-schists (6.4) or igneous phonolite (5.4). The stand located on bog iron deposits was not used in determining the average for slate schist soils.

Flora

The flora of the Black Hills and Bear Lodge Mountains is unique in that it contains species from the Rocky Mountain Region, the Northern Boreal Forest, the Northern Great Plains, and the Eastern Deciduous Forest (Buttrick 1914, Stephens 1973). The diversity of species within aspen stands reflects these origins. Rocky Mountain elements are represented by *Pinus ponderosa*, *Mahonia repens*, *Rosa woodsii*, and *Spiraea lucida*. *Betula papyrifera* and *Picea glauca* are representative of the Northern Boreal Forest, whereas *Quercus macrocarpa*, *Ostrya virginiana*, and *Aster laevis* are more characteristic of the Eastern Deciduous Forest. Species from the drier Northern Great Plains were not present in aspen habitats, presumably because of the mesic nature of these stands.

Other species in aspen stands of the Black Hills and Bear Lodge Mountains are found in all forest types, including woody draws in the prairies, across the temperate zone in North America. Examples of this group include *Populus tremuloides*, *Prunus virginianus*, *Symphoricarpos albus*, *Oryzopsis asperifolia*, *Poa pratensis*, and *Lathyrus ochroleucus*.

No one species growing in aspen understories was found in all 28 stands, although *Aster laevis* and *Lathyrus ochroleucus* occurred in 27. *Oryzopsis asperifolia*, *Rosa woodsii*, *Vicia americana*,

³Personal communication from John R. Jones, Rocky Mt. For. and Range Exp. Stn., USDA For. Serv., Flagstaff, Ariz.

Galium boreale, *Spiraea lucida*, and *Symphoricarpos albus* also occurred in more than 20 stands.

Marr (1967) and Hoff (1957) described *Arctostaphylos uva-ursi* and *Juniperus communis* as being common, vigorous plants in many aspen stands in the central Rocky Mountains (Colorado). Neither species, however, was found consistently in the Black Hills-Bear Lodge aspen. *Arctostaphylos uva-ursi* was found only in those aspen stands that contained some *Pinus ponderosa*, and *Juniperus communis* was found in five, but in significant amounts only in those stands on higher limestone plateaus. Both species are very common, however, in the *Pinus ponderosa* understories of the Black Hills (Thilenius 1972).

A total of 132 species of plants occurred on the transects within the 28 aspen stands studied. Included were 6 trees, 28 shrubs, 25 grasses or grasslike species, and 73 forbs. Forbs were the most numerous understory life form in all stands. Species of graminoids present exceeded shrubs in only six stands.

Canopy cover exceeded 100 percent in all but five stands. Average percent cover was 141. Reed (1971) found that the canopy cover exceeded 100 percent in 17 of 19 stands, and averaged 186 percent in the Wind River Mountains, Wyoming.

Vegetation Dynamics

In the eastern parts of its range, the successional status of quaking aspen has been reasonably well established: it is a seral stage that will be replaced by shade-tolerant northern hardwoods or *Abies balsamea* on most sites (Heinselman 1954, Curtis 1959). In the West, however, because of fewer species and more distinct forest types, aspen stands can appear to be permanent. The successional status of aspen in the West has provided spirited debate among ecologists since early papers by Featherolf (1917) and Baker (1918, 1925).

The question still remains unresolved, but several more recent studies of aspen have recognized the existence of some kinds of aspen stands that are apparently stable and should, therefore, be considered climax. Reed (1971), for example, found that the *Populus tremuloides*-*Symphoricarpos oreophilus* association was stable (climax) in the Wind River Mountains, Wyoming. His conclusion was based on lack of conifer replacement and the fact that aspen was apparently reproducing and therefore replacing itself. Wirsing (1973) also described a *Populus tremuloides*-*Carex geyeri* habitat type as being a climax association in the Medicine Bow Mountains of Wyoming.

Morgan (1969) stated that, from a management standpoint, aspen should be considered climax in Utah and western Colorado, but because aspen stands were less extensive in Gunnison County than in more western areas, conifers are reproducing and will replace most of the aspen. Other investigators have concluded or assumed that aspen is generally a seral stage that will eventually be replaced by conifers (Baker 1925, Oosting 1956, Hoff 1957).

Generalized statements concerning the seral position of aspen stands throughout the West cannot be made with confidence. Rate of succession varies not only between geographic areas, but also on different aspen sites within a physiographic province (Bartos 1973).

Differences in successional status of aspen stands in the Black Hills and Bear Lodge Mountains can most easily be described by looking at the individual Aspen Groups. AG's 3 and 4 contained middle-aged stands characterized by large aspen trees (see table 2). Neither AG had an appreciable number of seedlings (root suckers) in the understory, but both had a sapling component. AG-4 was missing two intermediate tree size classes of aspen, which indicated a disturbance that initiated root suckering without completely destroying the existing aspen overstory. All stands within the AG's contained seedlings or saplings of *Pinus ponderosa* or *Picea glauca*. These AG's were apparently composed of seral aspen stands that will eventually revert to *Pinus ponderosa* or *Picea glauca* communities.

AG-6 was similar to those described above except that the stand was younger and contained significant numbers of *Quercus macrocarpa*. *Pinus ponderosa* seedlings and saplings were present in greater densities than in any other AG. This AG was also a seral stage that will eventually be dominated by *Pinus ponderosa*, with a probable *Quercus macrocarpa* stratum similar to either Habitat Unit 6 or 7 as described by Thilenius (1972).

Two AG's, 8 and 9, contained aspen that, by Black Hills standards, were very old. Stands within these groups all contained moderate numbers of aspen in the 4- to 8-inch d.b.h. class. Two had larger specimens, whereas the only stand represented in AG-9 contained a few saplings. All had a few root suckers in the understory (see table 3). All stands were characterized by having a distinct, heavy shrub stratum composed of *Corylus cornuta* or *Ostrya virginiana*. No conifer reproduction was present. Two factors, the relative old age of the stands and the complete lack of conifer reproduction, indicated comparatively stable stands. Admittedly, aspen did not appear to be replacing itself as vigorously as might be

expected if it were a true climax community as noted by Reed (1971). However, some reproduction was present although certain size classes were missing. Missing size classes were also characteristic of some climax stands described by Reed (1971).

Limited aspen reproduction in stands with a heavy brush understory may result in a very gradual deterioration, leading to a limited stand of aspen with a greatly increased brush component which Heinselman (1954) and Hansen and Kurmis (1972) noted in some aspen stands in Minnesota. Bartos (1973) also suggested that at some point "...relatively stable stands would start to deteriorate until some perturbation caused the aspen community to revert to an earlier stage." Although there may be some disagreement as to what relative stability means in terms of climax, we tend to agree with Morgan (1969), in that such stability does indicate climax from a resource manager's point of view.

AG-7, represented by one young stand, had a fairly dense aspen overstory of trees in the 4- to 8-inch size class. Aspen and conifer reproduction were virtually nonexistent. The actual seral status cannot be determined at this time but, conceivably, the existing overstory could remain relatively dormant with individual stems gradually dying out while the *Corylus cornuta*, now present in the understory (see table 3), becomes abundant and vigorous. If such a pattern emerged, this stand would develop as those previously described.

Aspen Groups 1 and 2 contained dense stands of small aspen with few larger trees. All stands were relatively young, and 30 percent were being invaded by either *Pinus ponderosa* or *Picea glauca*. Again, because of the age of stands, successional status cannot be determined. As suggested by Bartos (1973), it is conceivable that, initially, both seral and stable aspen stands would react similarly. However, those with conifers could be expected to develop as true seral stages as described for AG's 3 and 4. Other stands, particularly those which contain *Corylus cornuta*, could develop into stable stands exemplified by AG's 8 and 9.

AG-5, which included three young stands and one old stand, was characterized by a moderately dense aspen overstory with an understory dominated by *Poa pratensis*. One of the younger stands contained a few *Pinus ponderosa* seedlings. All of the stands in AG-5, because of the nature of their understories and proximity to free water, were heavily grazed by cattle. The combination of heavy grazing and *Poa pratensis* sod could suppress both conifer reproduction and aspen suckering. Ellison and Houston (1958) noted that the spread of aspen into openings was often "held in

check" by browsing of new shoots. It has been suggested that the moist *Poa pratensis* meadows described by Pase and Thilenius (1968) are actually aspen sites that, under protection from heavy grazing, would support healthy aspen stands.⁴ Overgrazing, if continued until the existing aspen trees died, could result in a grassland type dominated by *Poa pratensis*. If grazing were restricted in this AG now, conifers would probably invade the stand (as suggested by the presence of conifer seedlings in one stand) or aspen root suckering would perpetuate the stand.

There is ample evidence in the literature that aspen invades or is established on favorable sites after fire (Hoff 1957, Severson 1964, Morgan 1969, Patton and Avant 1970, Gruell and Loope 1974). Of the 28 stands sampled in the Black Hills and Bear Lodge Mountains, 21 contained some evidence of past fires. Many of these burned sites had apparently been previously occupied by *Pinus ponderosa*.

Morgan (1969) concluded that scarcity of seed source plus lack of a base mineral soil accounted for the lack of coniferous reproduction within aspen stands. Jones (1974), however, noted that in Colorado, many aspen stands showed no significant coniferous invasion even with a seed source nearby. In the Black Hills and Bear Lodge Mountains, *Pinus ponderosa* is a dependable seed producer (Boldt and Van Deusen 1974) and natural reproduction is abundant. Even in extensive aspen stands there were many remnants of *Pinus ponderosa* that produced seed.

Conifer invasion appears to be related to the density of the understory, if factors such as the age of the aspen stand and time since the last fire are considered. Conifer reproduction was virtually absent in stands with a *Poa pratensis* sod, and in those with a dense understory of vigorous, taller shrubs such as *Corylus cornuta* and *Ostrya virginiana*. Therefore, although *Pinus ponderosa* may have dominated a site before fire, subsequent conifer reinvasion depended on site characteristics, intensity of the burn, and chance factors that determined which species became established on the site. If such conditions allowed the development of a competitive aspen-tall shrub type, conifer reproduction could be excluded indefinitely. Although this phenomenon might be considered disclimax by some, the fact that the type exists long after the disturbing factor has been removed indicates that fire climax might be a more appropriate term. The AG with a *Poa pratensis* understory could, however, be considered a disclimax, because, although the type

⁴Personal communication from G. W. Gullion, Univ. Minn., Cloquet For. Center, Cloquet, Minn.

originated due to fire, it is being held (or possibly further repressed) in such a state by grazing. If this disturbance were removed, succession would proceed toward a fire climax dominated by aspen or a true climatic climax dominated by *Pinus ponderosa* (Daubenmire 1968).

Applications of the Classification

Thilenius (1972) thoroughly discussed the validity of a classification system developed by cluster analysis of a similarity matrix for *Pinus ponderosa* communities. This discussion is equally appropriate to aspen classification.

Such a classification has limitations, of course, which should be overcome as our knowledge of the subject increases. One limitation evident in this study is the weakness of AG's represented by a single stand. It should be pointed out, however, that so long as study stands are selected in a random manner, single-stand AG's will most likely occur, regardless of the number of stands sampled. The only way to overcome this would be to select stands for analysis that would probably fit into a particular AG. This would inflate the frequency of occurrence in the least important AG's. The AG's we will be selecting for intensive analysis will be the most important ones—those with the greatest number of stands. Also, the stand AG's defined here are distinctly different from the others. We therefore believe the classification scheme used adequately serves the intended purpose—to separate relatively homogeneous aspen groups from the larger heterogeneous aspen complex. Areas for further intensive analysis can be selected from these relatively homogeneous units.

The classification scheme may also be used by management to select those stands which could be treated for predetermined responses. Preferred white-tailed deer habitats, for example, include those aspen stands which contain *Pinus ponderosa* (seral aspen stands in advanced stages of succession, Kranz and Linder 1973). Classification of aspen stands in the Black Hills would expedite selection of communities which could best be managed for such a response.

Ruffed grouse habitat, on the other hand, should not include conifer types, particularly *Picea glauca*, because conifers furnish optimum cover for most ruffed grouse predators (Gullion and Svoboda 1972). These investigators also noted that aspen buds, catkins, or leaves are primary ruffed grouse foods all year. Flower buds of male aspen and buds of *Corylus cornuta* ranked 1 and 2, respectively, as grouse foods in winter. Management of the relatively stable stands with

heavy *Corylus cornuta* understory could best serve the habitat needs of ruffed grouse. Management would still be necessary in such stands, however, to create the variety of aspen age and density classes necessary for optimum grouse habitat (Gullion and Svoboda 1972).

Summary

Twenty-eight aspen stands located throughout the Black Hills and Bear Lodge Mountains were subjected to cluster analysis of a similarity matrix based on the ecological attributes of vegetation, soil, and site characteristics. This analysis produced a classification of the aspen complex into nine Aspen Groups (AG) with a minimum internal similarity of 60 percent.

The indicator tree, shrub, grass, and forb species and the number of stands included in each AG are:

- AG-1: *Populus tremuloides*/*Spiraea lucida*/*Lathyrus ochroleucus* (eight stands)
- AG-2: *Populus tremuloides*/*Symphoricarpos albus*/*Pteridium aquilinum* (two stands)
- AG-3: *Populus tremuloides*/*Mahonia repens*/*Oryzopsis asperifolia* (seven stands)
- AG-4: *Populus tremuloides*/*Ribes missouriense*/*Oryzopsis asperifolia* / *Aster laevis* (one stand)
- AG-5: *Populus tremuloides*/*Rosa woodsii*/*Poa pratensis*/*Trifolium repens* (four stands)
- AG-6: *Populus tremuloides*/*Physocarpus monogynous*/*Poa pratensis*/*Smilacina stellata* (one stand)
- AG-7: *Populus tremuloides*/*Rubus parviflorus*/*Agropyron subsecundum*/*Aralia nudicaulis* (one stand)
- AG-8: *Populus tremuloides*/*Corylus cornuta*/*Aralia nudicaulis* (three stands)
- AG-9: *Populus tremuloides* / *Ostrya virginiana* / *Oryzopsis asperifolia* / *Aralia nudicaulis* (one stand)

All aspen stands were found on sites that indicated cool, moist situations (north-facing slopes). Soil development was poorly correlated with understory vegetation. The only consistent feature common to all profiles was the presence of an A₁ horizon with a granular structure.

Aspen stands within the Black Hills and Bear Lodge Mountains exhibited differences in successional status. Stands within AG-3 and AG-4 were seral stages that will eventually revert to *Pinus ponderosa* or *Picea glauca*. AG-8 and AG-9 are composed of relatively stable aspen stands with a heavy shrub understory.

The classification scheme developed here can be a useful tool for research and management. Representative aspen stands can be selected for further intensive studies from the relatively homogeneous units developed by cluster analysis of a similarity matrix. Resource managers can also use the classification to identify stands that could be treated for predetermined responses to create optimum habitat for wildlife.

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Aspen forests were classified into nine "Aspen Groups" by cluster analysis of a similarity matrix. Attributes used in analysis were based on vegetation, soils, and site characteristics. Aspen Groups were defined at a minimum similarity level of 60 percent. Relationships of soils, flora, and vegetation dynamics—within and between Aspen Groups—are discussed. Aspen Groups delineated by this method can be functional units for both research and management purposes.

Keywords: Quaking aspen, *Populus tremuloides*, classification, cluster analysis, synecology.

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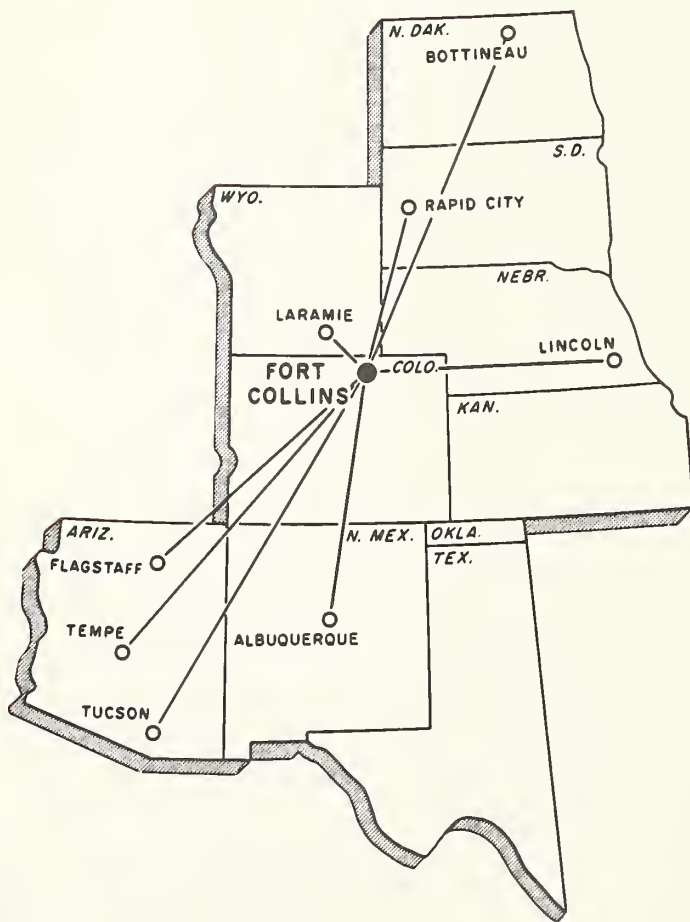
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